REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01-04-2010	Final	01-03-2008 - 28-2-2010

4. TITLE AND SUBTITLE
Understanding Lateral Mixing in the Ocean: 100 m to 1 km

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-08-1-0552

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Levine, Murray D
Cervantes, Brandy K
Pierce, Stephen D

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Oregon State University
College of Oceanic & Atmospheric Sciences
104 Ocean Admin Bldg
Corvallis, OR 97331

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Reserach
875 North Randolph Street
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR 32

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited distribution

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Horizontal dispersion of momentum and scalar quantities by submesoscale processes in the ocean remains an under-studied topic. The physical forcings that potentially contribute to horizontal dispersion are many, such as, wind stress, frontal dynamics, river input and internal waves. Typically, regional numerical models use simple horizontal diffusion to parameterize the complex horizontal dispersion , producing variability at horizontal scales of 100 m to 1 km and time scales of hours to days. To improve model parameterization of horizontal dispersion, we need additional observations and a better understanding of the processes involved. The focus is on tasks that are intended to help in the planning of a larger coordinated effort.
The specific components of the proposed research include:
• participation in a planning study group to develop a coordinated multi-year program.
• testing of our dye tracking equipment and instrumentation and assessment of their condition.

15. SUBJECT TERMS
Physical oceanography, Lateral mixing, Dye tracking

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Murray Levine
U	U	U	UU		19b. TELEPHONE NUMBER *(Include area code)* 541-737-3047

FINAL Report -- Distribution approved for public release; distribution is unlimited

Using Dye to Study Lateral Mixing in the Ocean: 100 m to 1 km

Murray D. Levine, PI
Brandy K. Cervantes
Stephen D. Pierce
Oregon State University, 104 COAS Admin Bldg, Corvallis, OR 97331
phone: (541) 737-3047 fax: (541) 737-2064 email: Levine@coas.oregonstate.edu

Award Number: N00014-09-1-0460

LONG-TERM GOALS

The long-term goals of this research are to understand submesoscale processes causing horizontal dispersion of momentum and scalar quantities. We are interested in these processes in the open ocean as well as their role in mixing the coastal ocean.

OBJECTIVES

The specific objectives of the proposed research are to:

- Continue participation with DRI investigators in planning a coordinated multi-year program,
- Conduct dye release experiments in conjunction with the observations planned by other DRI investigators to address DRI hypotheses, and
- Analyze experimental data and present results in DRI workshops, national scientific meetings and publications.

APPROACH

The approach for each of the three specific objectives is given below.

Planning for coordinated multi-year program. DRI planning meetings took place in Monterey in December 2008 and Chicago in June 2009. The next meeting will take place in December 2009 in Seattle. We will join the group of investigators involved in the DRI for the purposes developing and refining the experimental plans for field work scheduled from 2010 to 2012.

Conduct dye release experiments. In preparation for the major field experiments, we will test our equipment and dye-tracking technique in several short test cruises off Oregon.

The major field experiments are being planned for 2011 and 2012 by DRI investigators. As those plans are solidified, our specific role will become clear. We are currently planning on leading a west coast field test cruise in summer 2010 and participating in the major experiment in 2011. In 2011 we expect to perform several dye injections during the three-week field program, and track the dye using our towed vehicle systems (Minibat and ODIM Moving Vessel Profiler). We will cooperate with other investigators who may equip their platforms with dye fluorometers, such as, C. Lee (Triaxis from APL/UW), K. Shearman (gliders from OSU) and J. Klymak (MVP profiler from U Victoria).

Analyze experimental data. Data analysis will follow each of the field efforts. The objectives of the test cruises are to assess the performance of the sensor system as well as evaluate the software tools developed to assist in tracking the dye. Adjustments and improvements will be made where necessary.

Test cruises will also allow us to learn about the operations of other groups which will help us develop an experimental plan for the major experiments.

Following the major experiment in 2011, we will participate in a collaborative analysis with the other DRI investigators. We envision that part of the analysis effort will include DRI workshops leading to presentations at national meetings and publication in refereed journals.

WORK COMPLETED

We attended planning workshops in Monterey in December 2008 and Chicago in June 2009. DRI investigators discussed many facets of the project, including: determination of the guiding hypotheses, instruments available for data collection, possible field experiment locations, assignment of research tasks, and a program timeline.

Improvements were made to the dye tracking system in preparation for the 2009 test cruise (6 days), including: calibration of new fluorometers, addition of a second fluorometer on the CTD package used on the Minibat (to determine the different responses for pumped vs. open fluorometer configurations), and the development of real-time dye-tracking software.

The 2009 test cruise occurred during 27 August – 2 September onboard the R/V Wecoma. We selected a site about 40 miles off Newport, Oregon after looking at available satellite images to determine the location of a significant horizontal gradient in the SST field. For each of the three dye injections, we first conducted a short initial survey, then released the dye into the surface mixed layer, and subsequently tracked it with the towed Minibat CTD system (see Figure 1). A fluorometer was also hooked up to the ship's flowthrough system to continuously sample water at 5 m depth. A satellite-tracked surface drifter was deployed during the dye releases to serve as a guide to following the dye patch. The ship's ADCP provided real time velocity profiles that were used to predict the advection of the dye patch.

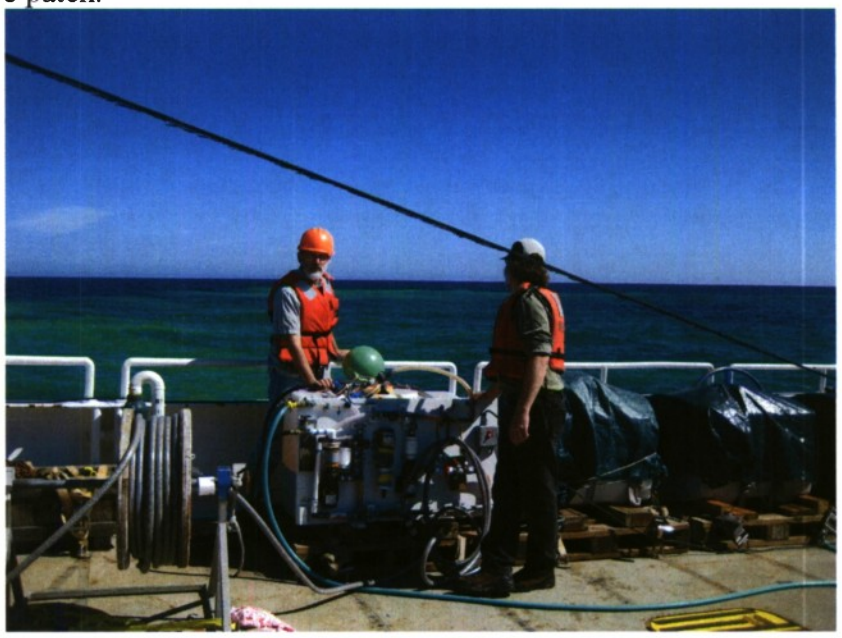

Figure 1. View of dye pumping system and surface release of fluoroscein dye from R/V Wecoma off Newport, Oregon, during the 2009 test cruise.

RESULTS

The 2009 test cruise provided valuable experience in conducting a dye tracking experiment. During the three dye release experiments we collected over 2000 vertical profiles with the towed Minibat system (see example in Figure 2), and the analysis is just beginning. The first step, which is underway, is to examine all the available data in order to determine how we can best address the DRI objectives. A fundamental objective is to determine the role and causes of vertical mixing and horizontal dispersion in shaping the evolution of the dye patch. Some preliminary results were presented at the 2010 AGU Ocean Sciences meeting in Portland, Oregon.

This analysis will also help us identify the modifications that need to be made in our methods and equipment in preparation for future field experiments.

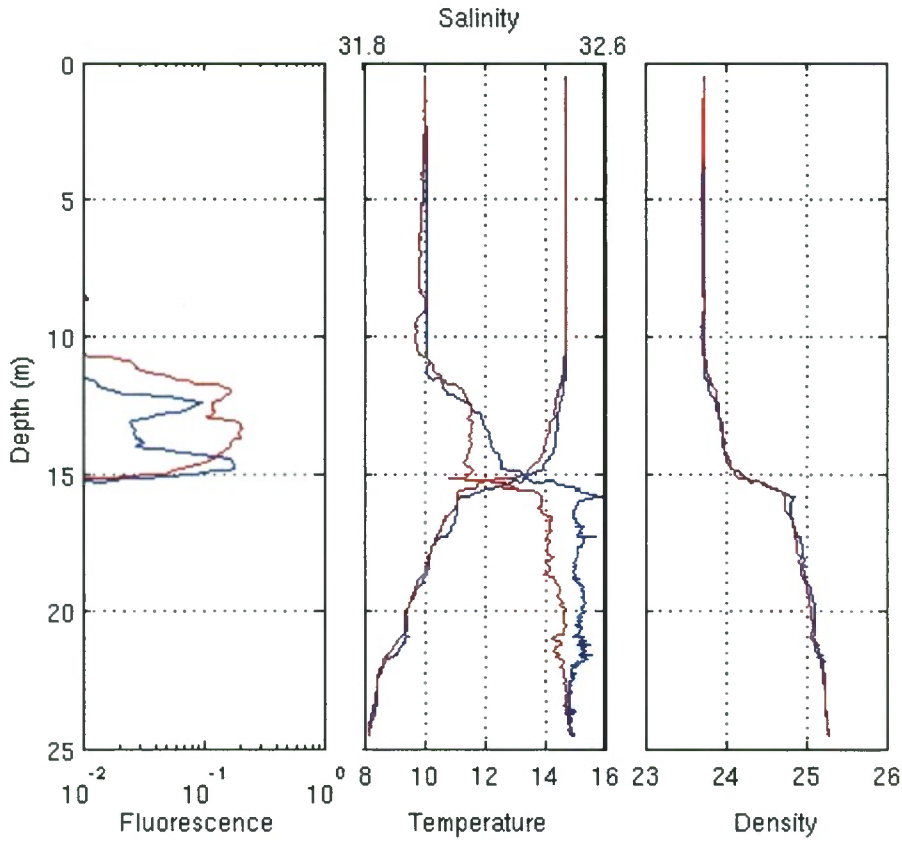

Figure 2. Vertical profile of dye fluorescence with salinity, temperature and density from the R/V Wecoma off the Oregon coast during the 2009 test cruise. Approximately 6 hours prior to these profiles the dye was injected into the surface mixed layer at 4 m depth at a density of 24 σ. At the time and location of these profiles the dye appears to have remained near its initial density, spread horizontally, and subducted under a mixed layer of density less than 24 σ.

IMPACT/APPLICATIONS

During the six-day Wecoma cruise we had the opportunity to take 3 oceanography graduate students and one engineering undergraduate student, who may not have otherwise had the opportunity to experience sea-going operations. A local high school teacher, who maintained a daily online log of the cruise to disseminate information to her students, also came along as part of the Teachers at Sea program.

RELATED PROJECTS

The observation and modeling of the coastal ocean off Oregon continues to be of great interest at OSU. Ultimately, improving understanding of the lateral mixing process will help in our ability to model coastal circulation.

Relating to the coastal ocean, the PI is currently involved in making continuous observations from a mooring at a site 10 miles off Newport (NH-10). Near-real time data are being collected and distributed on the web. This effort is funded by NOAA as part of the ocean observatory system, through the Northwest Association of Networked Ocean Observing Systems (www.nanoos.org and www.orcoos.org), and by NSF, through the Center for Coastal Margin Observation & Prediction (CMOP) (www.stccmop.org).

The PI is also involved in CMOP (as Co-Director) with a major goal of improving our understanding of the river to ocean system. Submesoscale processes are important in trying to understand horizontal dispersion and mixing of the river plume with the coastal ocean. We have had the opportunity to conduct several short a dye release experiment in the Columbia River plume, learning much about tracking dye in a very energetic environment.